

**APPLICATION**  
**FOR**  
**UNITED STATES LETTERS PATENT**

APPLICANT NAME: Ronald Clothier  
Jeffrey Alan Knight  
Robert David Sebesta

TITLE: STRUCTURE HAVING FLUSH  
CIRCUITRY FEATURES AND  
METHOD OF MAKING

DOCKET NO: END920000069US1

**INTERNATIONAL BUSINESS MACHINES CORPORATION**

CERTIFICATE OF MAILING UNDER 37 CFR § 1.10

IBM Docket No. END920000069US1

I hereby certify that, on the date shown below, this correspondence is being deposited with the United States Postal Service in an envelope addressed to the Commissioner for Patents, Washington, D.C. 20231 as "Express Mail Post Office to Addressee"

Mailing Label No. EK782889219US

on 05/23/01

Georgia Brundege

Name of person mailing paper

Georgia Brundege 5-23-01  
Signature Date

09863978-052301

Ronald Clothier, Jeffrey Alan Knight, Robert David Sebesta

Ronald Clothier, Jeffrey Alan Knight, Robert David Sebesta

The present invention relates to providing a protected, high density circuitry structure and method of fabrication.

The present invention provides a fine dimensioned planar circuitry structure and method which results in a smooth, protected high density circuitry pattern. The present invention is especially advantageous for fabricating buried connection levels that are in close proximity to one another in a printed circuit board structure and also advantageous for enabling clear spacer and finer features for gold wire band.

Printed circuit boards find a wide variety of uses in the electronics industry with the demand for high performance, printed wiring, or circuit boards for various applications steadily increasing. For instance, the complexity, compactness and electrical performance requirements of printed boards have significantly increased over the last several years.

The demands on printed circuit boards require high density packaging , fine interconnection, multilayer formation and the need to form a plurality of interconnections in a small space.

Currently, printed circuit board interconnection levels are built on top of a dielectric thin film layer. Circuitry features are formed using photolithographic and subtractive etch techniques. In a typical method, a metallic foil and especially copper foil is laminated to the substrate followed by using photolithographic and subtractive etching to create the circuitry.

09863978-053304

The copper foil includes a roughened or dendrite backside surface for inducing mechanical adhesion to the substrate. Smooth copper layers do not adequately bond without an auxiliary bonding agent.

5 Great difficulties exist in adequately etching dendrites especially when dealing with small spaces. Moreover, along with the concern created by dendrites, the thickness of the lines (e.g. about 0.5 mils wide), and photolithographic issues (e.g. resolution of fine features, 0.7 mil wire with 1.1 mil space, in a thin photo resist film), and subtractive etch undercut/pad rounding, render clearly and fully resolving small line spaces such as the 1.8 mil pitch features presently desired. Additionally, this subtractive etch approach results in

10 unprotected circuitry features referred to as "skyscrapers" that extend above an underlying plane of dielectric barrier material.

In many structures, it is important to plate another metal such as gold or nickel gold onto the copper circuitry. The "skyscraper" structure causes a problem of bridging or shortening between lines especially where there exist closely spaced fingers due to seed.

15

### SUMMARY OF THE INVENTION

The present invention provides for obtaining a structure having dense embedded flush circuitry features. The present invention makes it possible to create circuitry features that are much more densely configured than those fabricated using current methods. This is made possible since the final structure is a circuitry feature have dielectric regions and conductive features that are coplanar.

20

In particular, the present invention relates to a structure comprising a carrier foil; an electrically conductive layer on one of the major surfaces of the carrier foil; a dielectric layer located on the electrically conductive layer wherein the dielectric layer has circuitry features; and metal conductive circuitry located within the circuitry features wherein the metal conductive circuitry is flush with and surrounded by the dielectric layer.

25



Figures 4a-4h are schematic diagrams of the structure in progressive stages of fabrication according to a still further method of the present invention.

Figure 5 is a schematic diagram of a completed structure showing typical chip attach and gold wire bond from the chip to the flush planar surface circuitry that has been nickel-gold plated.

### BEST AND VARIOUS MODES FOR CARRYING OUT INVENTION

In order to facilitate an understanding of the present invention, reference will be made to the figures where the same numeral in different figures refers to the same member.

Figure 1a illustrates a carrier foil 1 typically a copper foil. The carrier foil 1 can include a top smooth metallized surface and a bottom rough or dendrite surface.

The foil is typically 9 to about 72 microns thick and more typically about 12 to about 18 microns thick. Typically, suitable copper foils include 0.5 oz and 1 oz foils.

Figure 1b illustrates blanket coating an electrically conductive layer 2 onto the top smooth metallized surface of carrier foil 1. An example of a suitable electrically conductive layer 2 is chromium which can be deposited by sputtering or evaporation. The layer 2 is typically about 500 to about 5000 angstroms thick and more typically about 800 to about 1500 angstroms thick.

Figure 1c illustrates coating the electrically conductive layer 2 with a dielectric material 3. The dielectric material 3 can be an inorganic dielectric such as silicon dioxides, silicon nitride and silicon oxynitride or a polymer dielectric material including photoimageable dielectric materials. The dielectric materials 3 is typically about 12 to about 55 microns thick and more typically about 18 to about 37 microns thick.

Examples of suitable photoimageable dielectric materials are polyimides.

The circuit features 4 are then defined in the dielectric material 3 such as by laser ablation. The circuit features are formed through the dielectric 3 up to the conductive layer 2 exposing the layer 2. For example, any of the known techniques for laser ablating can be employed. For instance, in the case of polyimides, the film is subjected to UV radiation of

308 nanometer wavelength. A commercially available source for such is the xenon chloride excimer laser.

The xenon chloride excimer laser as is well known, is designed for pulsed operation and, typically 200 mJ pulses/cm<sup>2</sup> are available at a repetition rate of about 300/second. This laser can be coupled to appropriate beam shaping and homogenizing optics to provide an apparatus for projecting a coherent beam through a mask. In general, intensities above about 60 mJ/cm<sup>2</sup> are employed for the laser ablating. Further detail of laser ablating of polyimides can be found for example, in U.S. Pat. No. 4,568,632, disclosure of which is incorporated herein by reference.

The circuit features are typically separated about 0.5 to 3.0 mils. Some circuit features may be as large as 1 inch length by 1 inch width to allow an electronic component such as a silicon chip to reside in the structure. The top surface and circuit features can then be blanket seeded (not shown) by depositing a relatively thin seed layer of a conductive metal. Typical metals include copper and chromium with copper being preferred. The seed layer is typically about 0.2 to about 2.5 micrograms per square centimeters. The seed layer can be deposited by electroless plating.

A conductive material such as copper is then blanket plated onto the seed layer (see Fig. 1d). The conductive film can be deposited by electroless plating, electroplating, sputter coating or evaporation techniques that are well known in the art. The preferred method of depositing the conductive film is by electroless plating.

The plated conductive material 5 is then planarized such as employing chemical mechanical polishing to achieve an alternating metal /dielectric high density circuitry structure 9 having a first flush planar circuitry surface 8 (see Figure 1e).

The structure 9 can be employed in single layer of a multi-layer structure by attaching the flush planar circuitry surface 8 to a stiffening dielectric layer 6 such as pre-preg by lamination or by coating with a film or aqueous resist such as a photo imageable dielectric (PID). Pre-pregs are typically dielectric polymeric materials such as epoxides or polyimides reinforced with woven or non-woven fibers such as fiberglass. The use of PID

for layer 6 allows interconnects to subsequent layers of metalization thru either standard photo chemical, laser or mechanical techniques such as drilling. In addition, the use of PID for layer 6 allows it to be machined thru laser or photo chemical techniques to contain features for the next layer for flush circuitry. Layer 6 also provided mechanical robustness needed for the following processing. See Figure 1f for an example of a multilayer structure.

Next the carrier foil 1 can be removed such as by etching in a suitable etchant (see Figure 1g). The layer 2 such as the chromium acts as an etch mask to protect the underlying conductive material 5 during the removal of carrier foil 1. The layer 2 is a different material than foil 1 and conductive material 5.

As illustrated in Figure 1h, the conductive material 2 can be removed since it is no longer required. It can be removed by etching in a suitable etchant.

The two second flush planar circuitry surfaces 13 now revealed are ideal for subsequent metalization of the circuit lines and features. For example, the planar surface the circuitry is flushly embedded in, allows these circuit lines and features to be gold/nickel-gold plated by standard techniques as well know in the art to even finer features and spacing without the traditional bridging problems. Gold deposition may be done selectively and with different types of gold such as hard or soft to enable optimization of both connectors and gold wire bond. Moreover, the multiple structure obtained pursuant to the above processing can then be joined together to form a multilayer circuit board.

Figure 2a illustrates a carrier foil 1 typically a copper foil. The carrier foil 1 can include a top smooth metallized surface and a bottom rough or dendrite surface. The foil is typically about 9 to about 140 microns thick and more typically about 12 to about 18 microns thick. Typically suitable copper foils include 0.5 oz and 1 oz. for typical electronic circuits. In cases where the foil will also serve the purpose of a stiffener such as for chip attach the typical foil will be about 10 oz.

Figure 2b illustrates blanket coating an electrically conductive layer 2 onto the top smooth metallized surface of carrier foil 1. An example of a suitable electrically conductive layer 2 is chromium which can be deposited by sputtering or evaporation. The layer 2 is

typically about 500 to about 5000 angstroms thick and more typically about 800 to about 1500 angstroms thick.

Figure 2c illustrates coating the electrically conductive layer 2 with a dielectric material 3. The dielectric material 3 can be an inorganic dielectric such as silicon dioxide, silicon nitride and silicon oxynitride or a polymer dielectric material including photoimageable dielectric materials. The dielectric material 3 is typically about 12 to about 105 microns thick and more typically about 18 to about 55 microns thick when circuit features 4 and defined by laser. The dielectric material 3 is typically about 250 microns to about 750 microns thick and more typically about 400 to 600 microns thick when circuit features 4 are formed by embossing. It is also possible to form features in the dielectric layer 3 with a mix of both laser and embossing as long as the thickness is sufficient (250 microns minimum) to support the embossing.

Examples of suitable photoimageable dielectric material are polyimides. The circuit features 4 are then defined in the dielectric material 3 such as by laser ablation or embossing. The circuit features formed in the dielectric layer 3 are not deep enough to expose layer 2. For example, any of the known techniques for laser ablating can be employed. For instance, in the case of polyimides, the film is subjected to UV radiation of 308 nanometer wavelength. A commercially available source for such is the xenon chloride excimer laser.

The xenon chloride excimer laser as is well known, is designed for pulsed operation and, typically 200 mJ pulses/cm<sup>2</sup> are available at a repetition rate of about 30/second. This laser can be coupled to appropriate beam shaping and homogenizing optics to provide an apparatus for projecting a coherent beam through a mask. In general, intensities above about 60 mJ/cm<sup>2</sup> are employed for the laser ablating. Further details of laser ablating of polyimides can be found for example, in U.S. Pat. No. 4,568,632, disclosure of which is incorporated herein by reference.



The circuit features are typically separated about 0.5 to 3.0 mils. Some circuit features may be as large as 1 inch length by 1 inch width to allow an electronic component such as a silicon chip to reside in the structure.

5 The top surface and circuit features can then be seeded (not shown) by depositing a relatively thin seed layer of a conductive metal. Typical metals include copper and chromium with copper being preferred. The seed layer is typically about 0.2 to about 2.5 micrograms per square centimeter. The seed layer can be deposited by electroless plating.

10 A conductive material 5 such as copper is then blanket plated onto the seed layer (see Figure 2d). The conductive film can be deposited by electroless plating, electroplating, sputter coating or evaporation techniques that are well known in the art. The preferred method of depositing the conductive film is by electroless plating.

15 The plated conductive material 5 is then planarized such as employing chemical mechanical polishing to achieve an alternating metal/dielectric high density circuitry structure 10 having flush planar circuitry surface 8 (see Fig. 2e). If ISOP is the final structure sought (fig.2e) the flush planar surface 8 is ideal for subsequent metalization of the circuit lines and features. For example, the planar surface the circuitry is flushly embedded in, allows these circuit lines and features to be gold/nickel-gold plated by standard techniques as well as known in the art to even finer features and spacing without the traditional bridging problems. Gold deposition may be done selectively and with different types of gold such as hard or soft to enable optimization of both connectors and gold wire bond.

20 The structure 10 can be employed in single layer or a multi-layer structure by attaching the flush planar circuitry surface 8 to a stiffening dielectric layer 6 such as pre-preg by lamination or by coating with a film or aqueous resist such as a photoimageable dielectric (PID). Pre-pregs are typically dielectric polymeric materials such as epoxides or polyimides reinforced with woven or non-woven fibers such as fiberglass. The use of PID for layer 6 allows interconnects to subsequent layers of metalization thru either standard photo chemical, laser or mechanical techniques such as drilling. In addition the use of PID

for layer 6 allows it to be machined thru laser or photo chemical techniques to contain features for the next layer of flush circuitry. Layer 6 also provided mechanical robustness needed for the following processing. See Figure 2f for an example of a multilayer structure.

5 Next, the carrier foil 1 can be removed such as by etching in a suitable etchant (see Fig. 2g). The layer 2 such as the chromium acts as an etch mask to protect the underlying conductive material 5 during the removal of carrier foil 1. The layer 2 is a different material than foil 1 and conductive material 5.

10 As illustrated in Figure 2h, the conductive material 2 can be removed since it is no longer required. It can be removed by etching in a suitable etchant. This results in a fully dielectric encapsulated two layer circuit structure 22. Electrical interconnects can now be made thru dielectric layers 3 to conductive circuit features 5 by standard photo chemical, laser or mechanical drilling. In addition dielectric layers 3 can have features formed in it to contain the next layer of conductive circuitry.

15 Moreover, the multiple structure obtained pursuant to the above processing can then be joined together to form a multilayer circuit board.

Figure 3a illustrates a carrier foil. The carrier foil 1 can include a top smooth metallized surface and a bottom rough or dendrite surface. The foil is typically 9 to about 72 microns thick and more typically about 12 to about 18microns thick. Typically suitable copper foils include 0.5 oz and 1 oz.

20 Figure 3b illustrates blanket coating an electrically conductive layer 2 onto the top smooth metallized surface of carrier foil 1. An example of a suitable electrically conductive layer 2 is chromium which can be deposited by sputtering or evaporation. The layer 2 is typically about 500 to about 5000 angstroms thick and more typically about 800 to about 1500 angstroms thick.

25 Figure 3c illustrates coating the electrically conductive layer 2 with a dielectric material 3. The dielectric material 3 can be an inorganic dielectric such as silicon dioxide, silicon nitride and silicon oxynitride or a polymer dielectric material including photoimageable dielectric materials. The dielectric material 3 is typically about 12 to about

55 microns thick and more typically about 18 to about 37 microns thick. Examples of suitable photoimageable dielectric material are polyimides.

The circuit features 4 are then defined in the dielectric material 3 such as by laser ablation. The circuit features are formed through the dielectric layer 3 up to the conductive layer 2 exposing the layer 2. For example, any of the known techniques for laser ablating can be employed. For instance, in the case of polyimides, the film is subjected to UV radiation of 308 nanometer wavelength. A commercially available source for such is the xenon chloride excimer laser.

The xenon chloride excimer laser as is well known, is designed for pulsed operation and, typically 200 mJ pulses/cm<sup>2</sup> are available at a repetition rate of about 300/second. This laser can be coupled to appropriate beam shaping and homogenizing optics to provide an apparatus for projecting a coherent beam through a mask. In general, intensities above about 60 mJ/cm<sup>2</sup> are employed for the laser ablating. Further details of laser ablating of polyimides can be found for example, in U.S. Patent No. 4,568,632, disclosure of which is incorporated herein by reference.

The circuit features are typically separated about 0.5 to 3.0 mils. Some circuit features may be as large as 1 inch length by 1 inch width to allow an electronic component such as a silicon chip to reside in the structure.

A conductive material 5 such as copper is then selectively plated onto the underlying conductive material 2 in the features defined in the dielectric layer 3 by the laser ablation of the dielectric layer 3 (see Fig. 3d). The underlying conductive material 2 can act as a seed for the plating. The conductive film can be deposited by electroless plating, electroplating, sputter coating or evaporation techniques that are well known in the art. The preferred method of depositing the conductive film is by electroplating.

The plated conductive material 5 is then planarized such as employing chemical mechanical polishing to achieve an alternating metal 1 dielectric of high density circuitry 11 having a first flush planar circuitry surface 8 (see Figure 3e).

The structure 11 can be employed in single layer or a multi-layered structure by attaching the first flush planar circuitry surface 8 to a stiffening dielectric layer 6 such as pre-preg by lamination or by coating with a film or aqueous resist such as a photo imageable dielectric (PID). Pre-pregs are typically dielectric polymeric materials such as epoxides or polyimides reinforced with woven and non-woven fibers such as fiberglass. The use of PID for layer 6 allows interconnects to subsequent layers of metalization thru either standard photo chemical, laser or mechanical techniques such as drilling. In addition the use of PID for layer 6 allows it to be machined thru laser or photochemical techniques to contain features for the next layer of flush circuitry. Layer 6 also provides mechanical robustness needed for the following processing. See Fig. 3f for an example of a multilayer structure.

Next the carrier foil 1 can be removed such as by etching in a suitable etchant (see Figure 3g). The layer 2 such as the chromium acts an etch mask to protect the underlying conductive material 5 during the removal of carrier foil 1. The layer 2 is a different material than foil 1 and conductive material 5.

As illustrated in Figure 3h, the conductive material 2 can be removed since it is no longer required. It can be removed by etching in a suitable etchant. The two second flush planar circuitry surfaces 13 now revealed are ideal for subsequent metalization of the circuit lines and features. For example, the planar surface the circuitry is flushly embedded in, allows these circuits lines and features to be gold/nickel-gold plated by standard techniques as well know in the art to even finer features and spacings without the traditional bridging problems. Gold depositions may be done selectively and with different types of gold such as hard or soft to enable optimization of both connectors and gold wire bond.

Moreover, the multiple structure obtained pursuant to the above processing can then be joined together to form a multilayer circuit board.

Figure 4a illustrates a carrier foil 1 typically a copper foil. The carrier foil 1 can include a top smooth metallized surface and a bottom rough or dendrite surface. The foil is typically about 9 to about 72 microns thick and more typically about 12 to about 18 microns thick. Typically suitable copper foils include 0.5 oz and 1 oz.

Figure 4b illustrates blanket coating an electrically conductive layer 2 onto the top smooth metallized surface of carrier foil 1. An example of a suitable electrically conductive layer 2 is chromium which can be deposited by sputtering or evaporation. The layer 2 is typically about 500 to about 5000 angstroms thick and more typically about 800 to about 1500 angstroms thick.

Figure 4c illustrates coating the electrically conductive layer 2 with a dielectric material 3. The dielectric material 3 can be an inorganic dielectric such as silicon dioxide, silicon oxynitride or a polymer dielectric material including photoimageable dielectric materials. The dielectric material 3 is typically about 12 to about 55 microns thick and more typically about 18 to about 37 microns thick. Examples of suitable photoimageable dielectric material are polyimides.

The circuit features 4 are then defined in the dielectric material 3 such as by laser ablation. The circuit features are formed through the dielectric layer 3 up to the conductive layer 2 exposing layer 2. For example, any of the known techniques for laser ablating can be employed. For instance, in the case of polyimides, the film is subjected to UV radiation of 308 nanometer wavelength. A commercially available source for such is the xenon chloride excimer laser.

The xenon chloride excimer laser as is well known, is designed for pulsed operation and, typically 200 mJ pulses/cm<sup>2</sup> are available at a repetition rate of about 300/second. This laser can be coupled to appropriate beam shaping and homogenizing optics to provide an apparatus for projecting a coherent beam through a mask. In general, intensities above about 60 mJ/cm<sup>2</sup> are employed for the laser ablating. Further details of laser ablating of polyimides can be found for example, in U.S. Patent No. 4,568,632, disclosure of which is incorporated herein by reference.

The circuit features are typically separated about 0.5 to 3.0 mils. Some circuit features may be as large as 1 inch length by 1 inch width to allow an electronic component such as a silicon chip to reside in the structure.



types of gold such as hard or soft to enable optimization of both connectors and gold wire bond.

The structure can be employed in single layer or a multi-layered structure by attaching the flush planar circuitry surface 20 to a stiffening dielectric layer 6 such as pre-preg by lamination or by coating with a film or aqueous resist such as a photo imageable dielectric (PID). Pre-pregs are typically dielectric polymeric materials such as epoxides or polyimides reinforced with woven or non-woven fibers such as fiberglass. The use of PID for layers 6 allows interconnects to subsequent layers of metalization thru either standard photo chemical, laser or mechanical techniques such as drilling. In addition the use of PID for layer 6 allows it be machined by laser or photo chemical techniques to contain features for the next layer of flush circuitry. See Figure 4h for an example of a multilayer structure.

Moreover, the multiple structure obtained pursuant to the above processing can then be joined together to form a multilayer circuit board.

Any of the above methods can be repeated as many times as desired to form a high density circuitry multi-layer structure. Known lamination processes can be used in achieving critical alignment to 0.1 microns.

Figures 2i, 2j and 2k illustrate one example of several possible interconnect formation sequences leading to a 4 layer electric circuit structure with various levels of interconnects shown. Starting with figure 2h as the base structure figure 2i illustrates formation of vias 14 thru the structure by any of several existing techniques such as laser, mechanical drill, or photo circuitize of the PID layers 3.

Figure 2j illustrates blanket seed (not shown) and conductive metallic plate 15 of the structure including the vias.

Figure 2k illustrates the results of selective subtractive etch circuitize process showing plated interconnects.

Figures 2l, 2m, 2n and 2o illustrate another example of possible interconnect formation sequences leading to a 4 layer electrical circuit structure with various levels of

interconnects shown. This example also shows the completed external surface to be flush planar circuitry.

Starting with structure 22 as shown in figure 2h as the base structure figure 2i illustrates attachment of additional PID layers 16 to form structure 24.

5 Figure 2m illustrates formation of vias 17 thru the structure 24 by any of several exiting techniques such as laser, mechanical drill, or photo circuitize of the PID layers 16. Figure 2m also illustrates formation of via to via interconnect features 23 in the dielectric layer 16 using the techniques previously illustrated in Figures 1 thru 4.

10 Figure 2n illustrates results of blanket seed (not shown) and metallic plate followed by filling the barrels of the plated vias with a paste 18 such as soldermask or even a conductive copper paste. The holefill is only needed if one intends to continue adding more circuit layers.

15 Figure 2o illustrates results of planarization by chemical mechanical polishing which produces external flush planar circuitry surfaces 19. The surfaces 19 are ideal for subsequent metalization of the circuit lines and features. For example, the planar surface the circuitry is flushly embedded in, allows these circuit lines and features to be gold/nickel-gold plated by standard techniques as well known in the art to even finer features and spacing without the traditional bridging problems.

20 Figure 5 illustrates a structure showing electrical component attach such as a silicon chip 25 and gold wire bond 26 connecting the electrical component to the flush planar surface circuitry 13 which as been coated with nickel/gold finish layer 27. In this structure 28 the component is attached to the underlying metal 1 by means of a thermally and electrically conductive adhesive 29 such as silver filled epoxy which serves to glue the component in place as well as transfer heat from the component to the underlying metal 1.

25 The underlying metal 1 also serves as a stiffening agent and is about 450 microns thick such as a typical 10 ounce copper foil.



The foregoing description of the invention illustrates and describes the present invention. Additionally, the disclosure shows and describes only the preferred embodiments of the invention but, as mentioned above, it is to be understood that the invention is capable of use in various other combinations, modifications, and environments and is capable of changes or modifications within the scope of the inventive concept as expressed herein, commensurate with the above teachings and/or the skill or knowledge of the relevant art. The embodiments described hereinabove are further intended to explain best modes known of practicing the invention and to enable others skilled in the art to utilize the invention in such, or other, embodiments and with the various modifications required by the particular applications or uses of the invention. Accordingly, the description is not intended to limit the invention to the form disclosed herein. Also, it is intended that the appended claims be construed to include alternative embodiments.